

## Equations

$ax^2 + bx + c = 0$ and $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	Quadratic Equation
$PV = nRT$	Ideal Gas Law
$P_T = \sum_i P_i$	Dalton's law of partial pressures
$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$	van der Waals equation
$Z = 1 + \frac{B}{V_m} + \frac{C}{V_m^2} + \frac{D}{V_m^3} + \dots$	Virial Equation
$Z = 1 + B'P + C'P^2 + D'P^3 + \dots$	Virial Equation
$\overline{E}_{trans} = \frac{3}{2} \frac{RT}{N_A} = \frac{3}{2} k_B T$	Average kinetic energy
$v_{rms} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{M}}$	Root-mean-square velocity
$\frac{dN}{N} = 4\pi c^2 \left(\frac{m}{2\pi k_B T}\right)^{3/2} e^{-mc^2/2k_B T} dc$	Maxwell speed distribution
$\overline{c} = \sqrt{\frac{8k_B T}{\pi m}} = \sqrt{\frac{8RT}{\pi M}}$	Average or mean speed
$c_{mp} = \sqrt{\frac{2k_B T}{\pi m}} = \sqrt{\frac{2RT}{\pi M}}$	most probable speed
$Z_1 = \sqrt{2}\pi d^2 \overline{c} \frac{N}{V}$	Collision frequency
$Z_{11} = \frac{\sqrt{2}}{2} \pi d^2 \overline{c} \left(\frac{N}{V}\right)^2$	Binary collision frequency
$\lambda = \frac{1}{\sqrt{2}\pi d^2 (N/V)}$	Mean free path
$\eta = \frac{m\overline{c}}{3\sqrt{2}\pi d^2}$	Gas viscosity
$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$	Graham's laws of diffusion and effusion
$\frac{N_2}{N_1} = e^{-\Delta E/k_B T}$	Boltzmann distribution law
$w = - \int p dV$	expansion work
$w = -nRT \ln \frac{V_2}{V_1} = -nRT \ln \frac{P_1}{P_2}$	work of isothermal, reversible ideal gas expansion
$\Delta U = q + w$	First law of Thermodynamics
$dU = \delta q + \delta w$	First law of Thermodynamics
$H = U + PV$	Definition of Enthalpy
$C_v = \left(\frac{\partial U}{\partial T}\right)_v$	Heat capacity at constant volume
$C_p = \left(\frac{\partial U}{\partial T}\right)_p$	Heat capacity at constant pressure
$P_1 V_1^\gamma = P_2 V_2^\gamma$	Adiabatic, reversible expansion of an ideal gas
$P = F/A$	pressure
$p = mv$	momentum

$S = k_B \ln W$	Boltzmann definition of Entropy
$\Delta S = nR \ln \frac{V_2}{V_1}$	Entropy change due to isothermal gas expansion
$\Delta S = \frac{q_{rev}}{T}$	Thermodynamic definition of Entropy
$dS = \frac{dq_{rev}}{T}$	Thermodynamic definition of Entropy
$\epsilon = \frac{ w }{q} = 1 - \frac{T_c}{T_h}$	Thermodynamic efficiency
$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr} \geq 0$	Second law of Thermodynamics
$\Delta_{mix} S = -R(n_A \ln x_A + n_B \ln x_B)$	Entropy change due to isothermal mixing
$\Delta_{mix} G = RT(n_A \ln x_A + n_B \ln x_B)$	change in Gibbs Energy due to isothermal mixing
$\Delta_{fus} S = \frac{\Delta_{fus} H}{T_f}$	Entropy change due to melting
$\Delta_{vap} S = \frac{\Delta_{vap} H}{T_f}$	Entropy change due to vaporization
$\Delta S = S_2 - S_1 = nC_{p,m} \ln \frac{T_2}{T_1}$	Entropy change due to heating at constant pressure
$\Delta S = S_T - S_0 = \int_0^T \frac{C_p}{T} dT$	Third Law Entropy
$G = H - TS$	Gibbs Energy
$dG_{sys} \leq 0$	At constant $T$ and $p$
$\Delta G = \Delta H - T\Delta S$	At constant $T$ and $p$
$A = U - TS$	Helmholtz Energy
$dA_{sys} \leq 0$	At constant $T$ and $V$
$\Delta A = \Delta U - T\Delta S$	At constant $T$ and $V$
$dU = TdS - pdV$	1st + 2nd law
$dG = Vdp - SdT$	G dependence on $T$ and $p$
$\left( \frac{\partial \left( \frac{\Delta G}{T} \right)}{\partial \left( \frac{1}{T} \right)} \right)_p = \Delta H$	Gibbs-Helmholtz Equation
$\Delta G = nRT \ln \frac{p_2}{p_1}$	Change in $G$ due to change in $p$
$G_m = G_m^\circ + RT \ln \frac{p}{p^\circ}$	Molar $G$ for a gas
$\frac{dp}{dT} = \frac{\Delta H_m}{T\Delta V_m}$	Clapeyron Equation
$\ln p = -\frac{\Delta H_m}{RT} + \text{constant}$	Clausius-Clapeyron Equation

$V = n_1V_{1,m} + n_2V_{2,m}$	Volume of a solution
$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,p,n_j}$	Chemical Potentials
$p_A = x_A p_A^*$	Raoult's law
$\mu_A = \mu_A^* + RT \ln x_A$	chemical potential of solvent in ideal mixture
$p_i = K_{x,i} x_i$	Henry's Law (mole fraction basis)
$p_i = K_{x,m} m_i$	Henry's Law (molality basis)
$\mu_B(p, T) = \mu_{x,B}^{ref}(p, T) + RT \ln x_A$	chemical potential of solute in ideal mixture
$\mu_B(p, T) = \mu_{x,B}^{ref}(p, T) + RT \ln a_A$	chemical potential of solute in real mixture
$a_i = \gamma_i x_i$	Definition of activity coefficient
$\Delta_r G^\circ = -RT \ln K_p$	$\Delta_r G^\circ$ and $K_p$ relationship
$\Delta_r G = \Delta_r G^\circ + RT \ln Q$	Gibbs energy change of a reaction
$\gamma = f/p$	Fugacity coefficient

	IA																		VIIIA
1	1.008 1H Hydrogen	IIA											III A	IVA	VA	VIA	VIIA	4.003 2He Helium	
2	6.941 3Li Lithium	9.012 4Be Beryllium												10.81 5B Boron	12.011 6C Carbon	14.007 7N Nitrogen	15.999 8O Oxygen	18.998 9F Fluorine	20.179 10Ne Neon
3	22.990 11Na Sodium	24.305 12Mg Magnesium	IIIB	IVB	VB	VIB	VIIB	VIII B			IB	IIB	26.98 13Al Aluminum	28.09 14Si Silicon	30.974 15P Phosphorus	32.06 16S Sulfur	35.453 17Cl Chlorine	39.948 18Ar Argon	
4	39.098 19K Potassium	40.08 20Ca Calcium	44.96 21Sc Scandium	47.88 22Ti Titanium	50.94 23V Vanadium	52.00 24Cr Chromium	54.94 25Mn Manganese	55.85 26Fe Iron	58.93 27Co Cobalt	58.69 28Ni Nickel	63.546 29Cu Copper	65.38 30Zn Zinc	69.72 31Ga Gallium	72.59 32Ge Germanium	74.92 33As Arsenic	78.96 34Se Selenium	79.904 35Br Bromine	83.80 36Kr Krypton	
5	85.47 37Rb Rubidium	87.62 38Sr Strontium	88.91 39Y Yttrium	91.22 40Zr Zirconium	92.91 41Nb Niobium	95.94 42Mo Molybdenum	(98) 43Tc Technetium	101.1 44Ru Ruthenium	102.91 45Rh Rhodium	106.4 46Pd Palladium	107.87 47Ag Silver	112.41 48Cd Cadmium	114.82 49In Indium	118.69 50Sn Tin	121.75 51Sb Antimony	127.60 52Te Tellurium	126.90 53I Iodine	131.29 54Xe Xenon	
6	132.91 55Cs Cesium	137.33 56Ba Barium	138.91 57La Lanthanum	178.49 72Hf Hafnium	180.95 73Ta Tantalum	183.85 74W Tungsten	186.2 75Re Rhenium	190.2 76Os Osmium	192.2 77Ir Iridium	195.08 78Pt Platinum	196.97 79Au Gold	200.59 80Hg Mercury	204.38 81Tl Thallium	207.2 82Pb Lead	208.98 83Bi Bismuth	(244) 84Po Polonium	(210) 85At Astatine	(222) 86Rn Radon	
7	(223) 87Fr Francium	226.03 88Rd Radium	227.03 89Ac Actinium																

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